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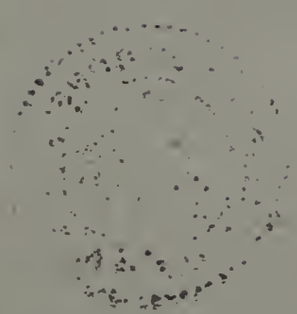

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PHOTOGRAPHS OF COMETS, AND OF THE MILKY WAY.

BY

E. E. BARNARD.

Photographs of Comets, and of the Milky Way. By E. E. Barnard.

I have, at various times, sent a number of photographs of the Milky Way, comets, &c., &c., to the Royal Astronomical Society, but these were not accompanied by any descriptions of the pictures.

It was my intention to describe in detail each one of these pictures to facilitate their study, and to put on record some of the more important features shown on the plates; for various reasons I was unable to do this when sending the pictures. I take the opportunity now, while sending a number of lantern slides from these and other pictures, to partially remedy the omission.

The Royal Astronomical Society has published some reproductions and lantern slides from the star and comet pictures previously sent. The present descriptions will also cover some of these, and for easy reference I shall indicate such pictures by the additional designation, *R.A S.*, No. —, the number being that given in the "List of Reproductions of Celestial Photographs published by the Royal Astronomical Society" (see page 210). At best, these descriptions will cover only a few of the total lot of pictures sent by me to the R.A.S. at various times.

A few brief remarks of an historical nature may perhaps be important before entering on the descriptions.

While connected with the Lick Observatory, a series of photographs was made of all the different portions of the Milky Way which were visible from that latitude. This work was begun in the spring of 1889. The instrument employed, as is well known, was a 6-inch portrait-lens of 31 inches focus, which bore the name of Willard, and the date 1859, and for this reason I have called it the "Willard lens" in all my work. This lens was used in the early days of wet plate photography for portrait work in a San Francisco photograph gallery. In the early times it was necessary to use a large aperture to lessen the duration of exposure in taking portraits; but after the invention of the quick dry plates, such a large lens became unnecessary, and this one was discarded for smaller and more convenient lenses.

Upon experimenting with this large lens, I found, on account of its wide field and great light-grasping power, that it was specially suited for the photography of the Milky Way, comets, &c. It was attached to a wooden camera box, and was first used by strapping it to the tube of the 6-inch equatorial. Latterly it was placed on an ordinary equatorial mounting, which did not permit continuous exposures to be carried across the meridian.

Besides the pictures of the Milky Way and nebulæ, a number of photographs were secured of Swift's Comet of 1892, Holmes's

Comet of 1892, Brooks's Comet of 1893, and Gale's Comet of 1894.

The photographs of the Milky Way made with the Willard lens were the first to show its cloud forms and general structure. They opened up the means for a thorough study of the Milky Way such as had not before existed. Indeed, it is safe to say that little or nothing was known of the structural peculiarities of the Milky Way before these photographs were made. Visual means, on account of the smallness of the field of view, could give only the vaguest and most uncertain ideas of its wonderful structure. But the extended views given us by the wide field of the rapid portrait lens, place before us the Milky Way in all its sublimity. Every rift and chasm is shown ; the cloud forms, the great nebulous regions, and the singular alignments of stars, are all faithfully portrayed for permanent study. It is through the study of these details that we shall ultimately know something definite concerning the universe of stars in which our own Sun is placed.

For the study of the phenomena of the tails of comets, the portrait lens has shown itself most admirably suited. It has added an interest to the physical study of these bodies that did not exist previously ; for the most interesting of the phenomena shown by comets must always escape the visual observer and pass unknown, without the aid of the portrait lens and the photographic plate. Unlike the planets, the comets often traverse the entire solar system. They are, therefore, our only means of exploring the regions between the planetary orbits. Instead of ponderous bodies like the planets, they are but flimsy creations of enormous dimensions. They are thus likely to be easily subject to disturbances in their forms that would produce no perceptible effect on their motions. What these influences may be we do not know ; probably swarms or streams of meteors, which we know do exist in space, or possibly some other cosmical matter yet unknown. Such objects might be (and possibly have been) revealed to us by their effect upon the form of the comet's tail as it sweeps through space.

Swift's Comet of 1892.

This was the first comet to show to the photographic plate the extraordinary changes to which these bodies are subject. Indeed, if it had not been for the photographic plate we should have known nothing of the extraordinary changes that occurred in this comet and several that have since appeared.

Photographs taken April 4 and 5 showed that very rapid changes were taking place in the comet ; these changes seemed to culminate in the extraordinury phenomenon of April 7.

A study of the various photographs of this comet would seem to show that the observed phenomena can readily be explained by

disturbances in the nucleus, and by the ejection of the matter composing the head in a direction away from the Sun.

1892 April 6^d 15^h 30^m—16^h 35^m. (Lantern slide.)

In this photograph there is no resemblance to the appearance of the comet on preceding dates.

The tail consists of two broad streams, the northern of which is very bright, and the southern faint. The two streams merge together near the head, and at this point there is a quick bend in its southern side. A great deal of detail is shown in the brighter component in the form of bright streaks and patches. Fine threads or short "whisker tails" extend back from the head at considerable angles to the main tail. There are some indications present also of the remarkable disturbance which followed some twenty-four hours later.

1892 April 7^d 15^h 45^m—16^h 35^m. (Lantern slide.) 25
R.A.S., No. 10.

This picture shows a remarkable development in the tail at the back of the head, which might be taken for a secondary comet with a system of tails of its own. This singular development appears on one of a series of thin strands into which the tail has separated. This particular strand is the largest and brightest and somewhat curved, and becomes suddenly thinner near the head. These phenomena are very beautifully shown on the photograph. The large mass or secondary comet was doubtless thrown off from the nucleus or head some time during the preceding twenty-four hours, and must have had a very considerable velocity.

1892 April 24^d 13^h 50^m—16^h 10^m. (Lantern slide.)

This is a generally characteristic view of the comet. The tail partially separates into a number of streams, and on the north side is very sharply defined by what appears to be a thin black rift; if this edge of the tail is continued to the comet, it will pass south of the centre of the head, and consequently does not appear due to a force at that moment seated in the nucleus. The south portion of the inner bright tail is irregular near the head, and in this resembles some of the peculiarities of the tail of April 6.

1892 April 26^d 13^h 45^m—16^h 10^m. (Lantern slide.)

The multiple structure of the tail is well shown. It appears to be made up of a number of bright strands which centre in the head.

28

Holmes's Comet and the Andromeda Nebula.

1892 November 21^{d} 8^{h} 55^{m}—10^{h} 10^{m}. (Lantern slide.)

The apparent motion of the comet was so slow that it was possible to obtain a sharp picture of both comet and nebula—a circumstance that is not likely to happen again soon.

The short exposure (75^{m}) for this picture shows splendidly the rapid action of the portrait lens. Nearly everything that is usually shown in long exposure photographs of the nebula is brought out very clearly with this comparatively short exposure. There is a bright speck in the comet near its preceding edge; this, however, was a fixed star, and not the nucleus, as might be supposed.

An earlier picture, November 10, shows the comet round and sharply defined like a planetary nebula, with a symmetrical nebulous atmosphere surrounding it for some distance. That photograph also shows an irregular nebulous appendage about a degree to the south-east of the comet and attached to it by a hazy connection. This particular photograph (a copy of which is in the possession of the *R.A.S.*, No. 17) is very suggestive, taken in connection with the collision theory offered by several astronomers to account for the sudden appearance of this body. It was suggested that the object was not a comet in the ordinary sense of the word, but the result of a collision of two asteroids, for the orbit seemed to lie in the asteroid zone. The failure to see the comet previous to its sudden apparition near the Andromeda Nebula, its uncometary appearance, its peculiar freaks, and final utter disappearance from the heavens, connected with the nebulous appendage shown in the photograph of November 10, would strongly suggest that the object was not a comet at all, but more probably a result of some celestial accident. I think there is no question but this "comet" will never be seen again, and doubtless before now it has ceased to exist as an individual body.

I do not wish it to be understood that I endorse the theory that the apparition of this object was due to the collision of two asteroids. It may have been due to something besides the collision of one asteroid with another. We know too little about what may really exist in that region besides the individual asteroids themselves. Certainly many of the phenomena presented by this body were entirely uncometary. In some of the stages of its existence, however, its appearance was perfectly cometary. I have a photograph of it on December 10, when its diameter was about $\frac{1}{2}$ degree. It was a well developed comet then, with a nucleus and central brightness and a diffusion of the head away from the Sun. This is a beautiful picture, and the stars shine through the comet everywhere. A month later, after it had become excessively faint and diffused, it suddenly (1893 January 16) assumed the form of a bright nebulous star, and again underwent a process of expanding and diffusion, and finally disappeared.

1893 *Brooks's Comet.*

Photographically this was the most remarkable comet that has yet appeared. It is scarcely necessary to say that had it not been for the photographs obtained of it with the Willard lens, we should have known nothing whatever of the extraordinary phenomena which were presented by this body, and which I am convinced will some day be seen to have a bearing upon a problem outside of that of the comet itself and of the highest importance to astronomy.

I have selected five of the photographs of this comet for description, four of which bear directly upon the subject just mentioned.

1893 October 20^d 16^h 35^m—17^h 10^m. (Lantern slide.)
R.A.S., No. 14.

This picture shows the tail straight, but gradually widening, and diffused more or less to the north. From the northern side of the head a short diffused tail stretches out for half a degree or more, at an angle of some thirty degrees to the main tail. The apparent motion of the comet was in a direction nearly perpendicular to the length of the tail towards the north-east, and this is the direction from which the disturbance seemed to come in the later pictures.

1893 October 21^d 16^h 37^m—17^h 12^m. (Lantern slide.)
R.A.S., No. 9.

There is an utter transformation of the comet in this picture. The tail is larger and brighter and very much distorted, as if it had encountered some resistance in its sweep through space. This disturbance seems to have disrupted the north-east edge of the tail. The small side tail has apparently been swept away, while the more distant portion of the main tail is streaming in a very irregular manner. The entire picture is highly suggestive of an encounter with some sort of resistance. Is it possible the tail passed through a stream of meteors such as we know exist in space? Whatever the cause may have been, the appearance of the tail utterly excludes the idea of the phenomenon being due to irregular emission of the matter from the nucleus—an explanation quite satisfactory in the case of Swift's Comet.

In passing, this particular photograph seems to explain at least one of the ancient descriptions of a comet, viz., "a torch appeared in the heavens." The comet, as shown in the photograph, is sufficiently suggestive of a torch streaming irregularly in the wind.

1893 October 22^{d} 16^{h} 30^{m}—17^{h} 12^{m}. (Lantern slide.)
R.A.S., No. 13.

The tail appears a total wreck in this photograph, and is still more suggestive of a disaster. It is very badly broken, and on the south-west side hangs in irregular cloud-like masses. Near the extremity a large gap exists in the tail, as if something had gone through it from the north-east, and a large mass is torn off beyond this break and seems to be drifting independent of the comet. Several of the other photographs which I obtained of this object show similar masses disconnected from the tail.

1893 November 2^{d} 16^{h} 10^{m}—17^{h} 25^{m}. (Lantern slide.)
(Plate 5.)

This is, perhaps, the next most remarkable picture of this comet, and shows that it was still in a disturbing region. The tail looks as if it were beating against a resisting force, and it seems to be encountered—as in all the photographs—on the advancing side of the tail. The motion of the comet was perpendicular to the tail towards the east, and, as will be seen, this is the direction from which the resistance seems to come. At one point the tail is nearly discontinuous, and at the end it is turned off abruptly nearly at right angles, as if at that point a greater current of resistance was encountered.

One or two other photographs show the tail badly broken and drifting in irregular fragments through space. These four pictures, however, are sufficiently characteristic of the phenomena shown by this comet to strongly suggest the idea that the tail must have encountered some form of resistance in its journey around the Sun, in this part of the heavens, on or about October 21, and at other times subsequent.

1893 November 11^{d} 15^{h} 58^{m}—17^{h} 35^{m}. (Lantern slide.)
(Plate 5.)

In this photograph, the tail of the comet is straight. It consists, at some distance from the head, essentially of two branches. The western branch is sinuous, as if matter were streaming irregularly back from the head, while the northern is very straight. At the end of the tail is a condensation which is nearly separated from the main tail.

A slender thread of light, beginning in the hinder part of the tail, stretches nearly to the end of the tail and forms the western border of the diffused western part of the tail. Near the head of the comet the tail is very slender and there are several small whisker tails from the rear of the head.

There is a small meteor trail crossing the south-western part of the plate parallel to the comet's tail.

1893 November $13^d\ 15^h\ 25^m$—$17^h\ 30^m$. (Lantern slide.) 26
R.A.S., No. 61.

This photograph perhaps properly belongs to the set of meteor pictures.

In the original negative the tail of the comet is shown in a straggling manner for some distance beyond the bright star (*a Can. Ven.*)

Perhaps the most singular thing about this picture is the fact that, though it was made on the morning of November 14, when there was a considerable number of bright Leonids, the great meteor shown on the plate was not a Leonid, for it was coming from the north, approximately towards the Leonid radiant. The meteor was seen with the eye as it shot across the sky and burst just off the region of the plate, but unfortunately the exact time was not recorded. It would not, however, be far from the middle time of the exposure. It was very brilliant—brighter than *Venus* at her greatest brilliancy.

Photographic Discovery of Comet V., 1892.

1892 October $12^d\ 6^h\ 40^m$—11^h. (Lantern slide, enlarged.)

$\alpha = 19^h\ 32^m$; $\delta = +12^\circ\ 50'$. 22

This comet was the first one to be discovered by the photographic plate. A photograph north and west of *Altair* was made, in my regular work of photographing the Milky Way. When the plate was developed and examined, a short hazy trail was found on it in $\alpha = 19^h\ 32^m$, $\delta + 12^\circ\ 50'$ (see *A.J.* 277). It was at once seen that the object was a stranger, as I was perfectly familiar with that part of the sky. It was too late to look it up that night with the telescope, but the next night it was sought for and found to be a very faint comet moving to the south-west. The discovery was telegraphically announced and the comet was generally observed. The orbit proved to be of short period—about $6\frac{1}{2}$ years.

Gale's Comet, 1894.

1894 May $5^d\ 8^h\ 45^m$—$11^h\ 15^m$. (Lantern slide.) 21

This is a characteristic photograph of the comet, which was mainly remarkable for the slenderness of its tail.

In this picture the tail is thread-like for some distance from the head. Further away it broadens out slightly, and separates into two or more parts. The northern edge of the tail appears to have a double curvature.

The phenomena presented by this comet were not very striking, though the changes in the tail were interesting. Only very slight traces of the tail could be seen with the telescope, and

these only quite close to the head, which was large and round, and did not seem to have anything to do with the formation of the tail, that is, there was no indication of the customary blending of the head into the tail.

Photographs of Meteors.

A nearly stationary meteor, 1894 August $9^d\ 14^h\ 17^m\ 4^s$. (Lantern slide.)

This is the time of the meteor's appearance. It was nearly stationary, with a short path about 12′ long. The motion was from the north-east to the south-west. The original plate shows two other fainter meteors.

A number of other meteors were photographed at different times during my work at Mount Hamilton, but this stationary meteor and the one shown on the photograph of Brooks's Comet, 1893 November 13, are the most remarkable.

1897 August $10^d\ 15^h\ 19^m$—$15^h\ 49^m$. (Lantern slide.)

This photograph was obtained with the Clark 3·4-inch doublet, which was kindly lent by the family of the late Alvan Clark, and which is a miniature of the Bruce 24-inch, and made from the same glass as that lens. The full flight of the meteor is shown on the plate. Before disappearing it burst, and beyond this point it left a faint trail as it died away. This gives the trail the appearance of a long shafted lance. Its path extends from $\alpha = 2^h\ 59^m$, $\delta = +32°$ to $\alpha = 2^h\ 59^m$, $\delta = +23°$.

1897 August $10^d\ 15^h\ 19^m$—$15^h\ 49^m$. (Lantern slide.)

This is the same meteor. The picture was made with a small lantern lens 1·6 in diameter belonging to Professor Hale.

This photograph not only shows the meteor train, but it also shows the Pleiades near the lower east part of the plate. It is a very beautiful picture apart from its scientific value. These two photographs were made at the Yerkes Observatory.

These meteor photographs were reproduced and fully described in *Popular Astronomy*, No. 46.

Photographs of the Milky Way.

Star Cloud in Sagittarius.

1892 June $29^d\ 9^h\ 25^m$—$13^h\ 55^m$. (Lantern slide.)

$\alpha = 18^h\ 10^m \pm$; $\delta = -20°$.

This plate shows a large star cloud in Sagittarius, remarkable for the two black holes in it. Running southwards from the larger and more definite of these holes is a semi-vacant region, which

branches out into two more or less regular semi-vacant lanes, which run for nearly a degree and a half from the hole. At the junction of these lanes, about 50′ from the hole, is a remarkable thread-like stream of small bright stars which extends about 20′ east and west. Curving slightly at its east end this line of stars makes a V-shaped connection with two or three other bright stars. At the southerly ends of the dark lanes are two delicate, thread-like streams of stars ; the southern one of these extends in a gentle curve for nearly $1\frac{1}{2}$ degree. This is a very striking phenomenon. A similar stream runs eastwards from near the upper part of the black hole. Indeed, this is a remarkable region for star streams, many of which can be picked out on this plate. In the northern part of the slide is shown the celebrated Omega Nebula, which loses its characteristic appearance on account of the greater extent of nebulosity which the photograph shows compared with what the eye sees. The nebulosity extends in a very diffused, fan-shaped manner for over half a degree to the eastward from the brighter portion.

About $1\frac{1}{2}$ degree south of the black hole is a group of nebulous stars. The largest star of this group is surrounded with a circular nebulosity some 20′ in diameter. Three degrees south of the hole is a bright star, with a partial ellipse of small stars extending south-eastwards from it. There are many other remarkable features about this plate, which will be at once apparent to the eye.

Near θ Ophiuchi.

1894 July 6^d 9^h 30^m—13^h 5^m. (Lantern slide.)

$\alpha = 17^h\ 15^m$; $\delta = -25°$. (Plate 6.)

This is certainly one of the most remarkable regions of the Milky Way. One would hesitate before coming to a conclusion as to what the ground work here is. Whether it is stars altogether, or some nebulosity, or something else, which is neither stars nor nebulosity (for it does not closely resemble either), it would be difficult to decide in one's mind. Besides the bed work of small stars, there seems to be possibly an infusion of nebulous matter over a large portion of the sky in this region. To the east and south of *θ Ophiuchi* is a vast chasm or rift in the sheetings of stars. This has a ragged but definite appearance on its western edge, but is more diffused to the east. To the west of the star *θ* will be seen an extended mass of diffused matter among the stars, which runs southward and partly bridges the western branch of the great rift. At the extreme western end of this rift—beyond the hazy diffusion—the vacancy has dark spots in it. Similar appearances occur at different points in this part of the sky. One can scarcely conceive a vacancy with holes in it, unless there is nebulous matter covering these apparently vacant places in which holes might occur. The appearance is somewhat like what

is sometimes seen in the umbra of a sunspot, in which yet blacker holes appear. North of θ are several minute black markings, one of which very much resembles the letter S or the figure 5. Two almost parallel semi-vacant streaks, running north and south, will be seen on each side of θ. Still farther north of θ the Milky Way presents a broken appearance, with numerous holes and rifts. These all show the peculiarity of darker interiors. This is specially shown in another photograph I have made with that region central.

This picture is suggestive of a breaking up or segregation of the stratum of stars and nebulosity—I am not sure it is nebulosity—in this portion of the Milky Way.

North of θ Ophiuchi.

1895 June 25^d 9^h 55^m—13^h 55^m. (Lantern slide.)

$\alpha = 17^h\ 15^m$; $\delta = -22°$.

This photograph shows still better some of the phenomena of the preceding picture. It brings out yet more remarkably the extraordinary nature of the holes and rifts in this part of the Milky Way. The phenomenon of darker holes in the vacancies is strikingly shown, and looking at the picture one cannot repress the thought that all this region of the Milky Way must have a substratum of nebulous matter mixed in freely with the ground work of stars.

The Region of 58 Ophiuchi.

1895 June 26^d 10^h 10^m—14^h 15^m. (Lantern slide.)

$\alpha = 17^h\ 35^m$; $\delta = -22°$. (Plate 6.)

This region joins on to the preceding one. It is quite unique, however, and the peculiar appearances shown on this plate are not repeated in any other part of the Milky Way.

The bright star in the middle of the slide is 58 *Ophiuchi*. This star occupies the centre of a most remarkable region of small, cloudlike masses, which in arrangement seem to have a slight spiral tendency. This region, like that of θ *Ophiuchi*, is one where some doubt as to the existence of slight nebulosity might arise. I do not feel certain, however, that these clouds are nebulous, for there is lacking that peculiar soft appearance always characteristic of the true nebulosities of the sky.

The Trifid Nebula and M. 8 are shown at the east edge of the plate. The cluster in the north-east quarter is M. 23.

This plate also shows the trail of an asteroid, which Dr. Berberich kindly identified as belonging to *Euterpe* (27), which was discovered in 1853 by Hind. To those interested in this planet the trail will be found $1\frac{1}{2}$ degree south of 58 *Ophiuchi*.

It will be easily found on the large 10×8 glass positive in the possession of the Royal Astronomical Society, which is from the same negative as the present lantern slide. Indeed, it can be picked out on the slide with a magnifier, 0·32 inch almost due south of 58 *Ophiuchi*, in a semi-vacant region, between two of the clouds.

The Nebulous Region of 15 *Monocerotis.*

1894 February 1^d 7^h 0^m—9^h 25^m, clouds then 9^h 50^m—10^h 25^m. (Lantern slide.)

$\alpha = 6^h\ 35^m$; $\delta = +10°$.

This plate shows well the large diffused nebulosity that extends some 3 degrees northwards from the condensed region about 15 *Monocerotis*. The nebulosity spreads over and partly veils a portion of the great vacancy which lies north and west of 15 *Monocerotis*. To the west of 15 *Monocerotis* is a curious nebula involving several considerable stars. In the upper part of this nebula are one or two remarkably small black holes. This object, which is extremely faint and diffused visually, was discovered with the 12-inch in 1888. The position of this nebula is 1860·0 $6^h\ 23^m\ 27^s + 10°\ 7'$. It involves the two D.M. stars +10°·1159 and +10°·1160. Close north of this nebula is a small nebulous star which was also discovered with the 12-inch in 1888. Its position is 1860·0 $6^h\ 23^m\ 14^s \pm$, $+10°\ 32'·6 \pm$. There is also a small vacancy in the nebulosity about this star, close south of the star.

At the south edge of the plate is shown a portion of Swift's nebula N.G.C. 2237.

If the plate is carefully examined, many curious lines of stars, vacant lanes, &c., will be seen. About 2 degrees south of 15 *Monocerotis* is one of these thin lanes or dark lines among the stars which, though extremely narrow, runs eastward for about 2 degrees.

Region of M. 11.

1895 August 16^d 8^h 25^m—13^h 35^m. (Lantern slide.)

$\alpha = 18^h\ 45^m$; $\delta = -6°$.

This magnificent star cloud is beautifully shown on this plate It was one of the first of the Milky Way clouds photographed in 1389.

The small cluster M. 11 lies on the upper or north edge of the neck of the large cloud, and looks like a nucleus. The western side of the great cloud has several rather sharply marked indentations and several detached masses of stars.

The star 6 *Aquilæ*, on the upper north edge of the great head, has two curious sprays of stars extending from it, giving the

appearance of a ram's horns. The great star cloud seems to be made up of very small stars, apparently very uniform in size. Near the left-hand corner of the plate is shown a beautiful bright nebulous star. This is S.D.M. 10°·4713 of the 5·5 magnitude. The position for 1855·0 is $18^h\ 23^m\ 23{\cdot}9^s$, S. 10° 53·4′. The nebulosity about this star is somewhat elliptical. It was discovered on the plates of 1889, and is quite noticeable visually. (See *Ast. Nach.* 3111, Bd. 130.) The bright star near the N.E. edge of the plate is λ *Aquilæ*. The great star cloud seems to stretch out to and surround this star.

Region of M. 8 and the Trifid Nebula.

1895 June $27^d\ 10^h\ 55^m$—$14^h\ 25^m$. (Lantern slide.)

$\alpha = 18^h\ 0^m$; $\delta = -24°$.

This slide is intended to show the appearance of the Milky Way in the immediate neighbourhood of these two nebulæ. It gives an excellent idea of the apparent relation they bear to the rest of the Milky Way. They appear to lie just free of the western border of a very brilliant portion of the Milky Way, in a partially vacant region, between the bright clouds and the region of 58 *Ophiuchi*. South of these objects is one of the most beautiful of all the regions of the Milky Way.

M. 8 and the Trifid Nebula.

The same as the preceding, on a larger scale.
(Lantern slide.)

This is intended to give a closer view of these objects, and to show their relation to each other and to a group of nebulous stars which lies about 1° east of M. 8. The latter is a very remarkable group. The stars are not simply involved in nebulosity, but each one is a distinct nebulous star. They are connected on the photographs by a delicate nebulous strip with M. 8. Several of these were originally discovered visually with the 12-inch.

In reference to this picture it is well to note one thing which might be misleading when compared with photographs of these objects with larger instruments, where the scale is greater. In dealing with the fainter and outlying portions of M. 8 the portrait lens is eminently suited, but for the details of the brighter parts a larger scale becomes necessary. These details are too crowded with the small scale, and the light action is so great that what are apparently vacant lanes and regions with a larger instrument are filled up and obliterated with the long exposure, thus producing an apparent difference in the appearance of the nebula with the portrait lens and with a greater telescope. For the details the difference is in favour of the larger telescope for a truthful representation of the nebula; or,

in other words, the small bright details of this nebula are not suitable subjects for a short-focus portrait lens, especially when using such long exposures as are required to bring out the fainter portions of the Milky Way. A comparatively short exposure would show these details more faithfully.

Great Star Cloud in Sagittarius.

1895 August 13^d 8^h 0^m—11^h 8^m. (Lantern slide.)

$\alpha = 17^h\ 56^m$; $\delta = -28°$. (Plate 7.)

This is a superb picture of the Milky Way. It most emphatically shows the great value of the portrait lens for work of this kind, where large details, covering a great region, are to be dealt with.

This beautiful region has always had a special charm for me, and I have secured a great many photographs of it. It was the first region to be photographed in 1889.

I can hardly believe that any one familiar with the sky can look on this picture without admiring the beauty of structure and detail shown on it. Outside of its scientific value, it is a picture in itself.

To the west of the centre is a great plume-like spray of stars that apparently is connected with a long rope-like nebula and streak of stars running nearly north and south for nearly 2 degrees. This nebulous rope of stars is a very singular feature. In some photographs of the region which I made with the small lantern lens it seems to stand out from the other details near it as if it were considerably nearer to us and not connected with the star plume, as it appears to be in this photograph.

In the bright region near the centre of the plate is a tiny black hole about $2'$ or $3'$ in diameter, well defined, and close preceding a small bright group of stars. It is so small and well defined on the plate as to look like a defect. The position of this object is $17^h\ 56^m$—$27°\ 51'$ (see *A.N.* 2588). It is a most remarkable object, with a low power on a 5 or 6-inch telescope. In examining this hole with the 36-inch, I found that its southern edge was made up of a dense mixture of milky nebulosity and small stars.

In the north part of the plate is shown M. 8 and the Trifid Nebula.

The Great Nebula of ρ Ophiuchi and the Vacant Regions near Antares.

1895 June 21^d 9^h 12^m—13^h 12^m; June 22^d 9^h 5^m—13^h 35^m. (Lantern slide.)

$\alpha = 16^h\ 20^m$; $\delta = -23°$.

It is very difficult to attempt a description of this picture. In the centre of the plate is the great nebula, in the centre of which *ρ Ophiuchi* is apparently placed. But this is only the

main condensation of this remarkable nebula. Its influence seems to be very far-reaching, as it has secondary condensations about at least two other stars, viz. Cordoba D.M. 24°·12683 and 24°·12684 and 22 *Scorpii*. The one about the Cordoba stars is the most striking, and seems to be made up of four curved streams, like the whirls of a great spiral. The great condensation about ρ *Ophiuchi* is most highly suggestive, and with a larger telescope would, no doubt, prove to be a most extraordinary object, as there are a great many remarkable details shown even on this small scale.

The great nebula occupies a vacant region from which vacant lanes stretch irregularly for great distances to the east. One remarkable feature about these dark lanes is the peculiarity before mentioned, of darker places in the vacant regions; this is strikingly shown in the present photograph. A nebulous prong is seen extending northwards for a short distance from the bright star, σ *Scorpii*, which is evidently connected with the great nebula. A large portion of the sky here seems to be covered with diffuse nebulosity, to which belongs the condensation about ρ *Ophiuchi* and the other stars. The peculiarity of this region has suggested to me the idea that the apparently small stars forming the ground work of the Milky Way here, are really very small bodies compared with our own Sun. (See *Popular Astronomy*, No. 45, where the subject is discussed in detail.)

In the upper north-west corner of the picture is the star ν *Scorpii*, which is seen to be involved in a singular wing-like nebula. East and south of ν are the two stars S.D.M. 19°·4358-9 and 4361, which are involved in dense nebulosity. The star 4361 is in the position 1855·0 $\alpha = 16^h\ 12^m\ 1^s$; $\delta = -19°46'$.

These objects were none of them known previous to the first photographs I secured of this region in 1895 March, with the exception that I had known of nebulosity in this region for many years through my comet sweeping.

I am glad to hear that Professor S. I. Bailey expects to take this great nebula up with the Bruce 24-inch at Arequipa, at its next apparition, as well as several other objects of this kind. The results will be exceedingly interesting.

The Nebula about ν Scorpii.

1895 May $23^d\ 9^h\ 0^m$—$12^h\ 20^m$. (Lantern slide.)

$\alpha = 16^h\ 5^m$; $\delta = -19°$.

ν *Scorpii* is one of Mr. Burnham's double stars. In photographing the region of the great nebula of ρ *Ophiuchi* in 1895 March, I made exposures at the same time with the $1\frac{1}{2}$-inch lantern lens. On the photographs, with this small lens, the star ν *Scorpii* was seen to be involved in dense nebulosity. This star fell at the edge of the Willard lens plate, but upon examination it was seen

that the larger lens had also shown the nebulosity, and this was repeated in subsequent pictures. The present plate is from a negative made with the Willard lens specially to show the nebula. It is seen to be a wing-like nebulosity, extending north, west, and south-east, with the bright star occupying, apparently, the centre of brightness. The nebula extends eastwards for some distance, where it seems to dull the sky, or where there are very few stars. It is well defined and brightest at its western edge. The photographs indicate that this nebula is probably connected with the great nebula of ρ *Ophiuchi*.

Region of β Cygni.

1893 October $12^d\ 6^h\ 52^m$—$11^h\ 35^m$. (Lantern slide.)

$\alpha = 19^h\ 25^m$; $\delta = +26°$.

This picture shows the cloud forms in the Milky Way, south and east of β *Cygni*.

Some 5° east of β the dense clustering of small stars rather abruptly terminates in great cloud masses. Beyond this the Milky Way is very thin, and permits the darkness of space to be seen between the stars. One is specially struck with the apparent extreme smallness of the general mass of stars in this region.

Region near χ Cygni.

1892 October $20^d\ 6^h\ 47^m$—$11^h\ 47^m$. (Lantern slide.)

$\alpha = 19^h\ 40^m$; $\delta = +33°$.

This region lies south of γ *Cygni*, which is seen in the north-east half of the photograph.

The north-west part of the plate is covered with a more or less uniform sheet of small stars, so densely crowded as to intercept the view of space beyond, while the south-east portion is overspread with a very thin sheeting of stars projected against the blackness of space. The contrast between the two conditions is very beautiful and striking. The stars here are also remarkably uniform in size.

The original negative shows a great deal of nebulosity about γ *Cygni* in the form of brightish strips and patches, which slightly give the impression of a spiral arrangement to the nebulosity ; these have been sacrificed, however, in the slide to show the structure of the Milky Way to the best advantage.

Nebulous Region near α Cygni.

1893 October $5^d\ 8^h\ 0^m$—$14^h\ 5^m$. (Lantern slide.)

$\alpha = 21^h\ 0^m \pm$; $\delta = +42° \pm$.

The plate shows the singular structure of the Milky Way at this point, and the great nebulosities that affect the sky in this

region. It will be seen that the greatest mass of nebulosity seems certainly to be mixed up with the stars, and conforms with the outline of the star masses at the edge of the greatest semi-vacancy. This region was first photographed by Dr. Max Wolf. The nebulosities are easily seen with almost any sized visual telescope when a low power is employed. I was for many years familiar with the nebulosity when seeking for comets, though I did not take it for real nebulosity. Indeed, this very nebulosity was discovered by William Herschel. In a list of great masses of diffused nebulous matter, in *Phil. Trans.* for 1811, pp. 273–278, he gives for number 44 of his list (1800·0 $\alpha = 20^h\ 51^m\ 4^s$ P.D. 46° 51′), with the note : "Faint Milky Nebulosity scattered over this space ; in some places pretty bright." He gives the size in declination as 0° 59′, and in right ascension 2° 53′, or 2·8 square degrees in area. This is undoubtedly the object shown on the photographs.

Region of N.G.C. 6475.

1894 June 26^d 9^h 5^m—12^h 10^m. (Lantern slide.)

$\alpha = 17^h\ 45^m$; $\delta = -35°\ 0'$.

This beautiful cluster is partly in a brilliant knot or condensation of the Milky Way.

About 3° north-east of the cluster is a small semi-vacant comma-shaped hole with a considerable star in its centre. This hole is about 12′ in diameter.

The Milky Way in Cepheus.

1893 October 13^d 8^h 20^m—15^h 20^m. (Lantern slide.)

$\alpha = 21^h\ 35^m$; $\delta = +57°$.

Near the centre of this plate is a large and singular nebulosity, remarkable for the irregular dark lanes that run into and through it. My first knowledge of this nebula was its presence near the edge of another plate. The present picture was made specially to see what the object was. It was found, as shown, to be a fine but very singular-looking nebula.

To the extreme west of the plate, and north of the centre, are two small stars near each other. One of these is strongly nebulous. It is one of Mr. Burnham's double stars (β 1140), while the other star close following it is Σ 2790. The larger star south of the centre of the plate is μ *Cephei*, while the one at the north edge is ν *Cephei*.

Region near the Omega Nebula (M. 17).

1895 July 25^d 9^h 35^m—14^h 0^m. (Lantern slide.)

$\alpha = 18^h\ 30^m$; $\delta = -15°$. (Plate 7.)

This is a very interesting region. The centre of the plate is covered by a large mass of stars which converges to a point at a vacant region in the north part of the plate. Indeed, nearly all the masses of stars in this region seem to tend towards this great vacancy, as if its formation had something to do with their general arrangement. In this hole shines the beautiful nebulous star previously mentioned (S.D.M. 10°·4713), which is perhaps better shown on this plate than on the others. To the south-west of the centre of the plate is the celebrated Omega or Swan Nebula (M. 17), and at the lower south-west corner is the fine star cloud, with the dark holes previously mentioned.

All the times given in these descriptions are eight hours slow of Greenwich, except the two plates made at the Yerkes Observatory, which are six hours slow of Greenwich. The positions given for all the pictures are only very roughly approximate.

It is perhaps well to state that in none of my work has any retouching been resorted to. Every photograph is free from any blemish of that kind, which, however it may be tolerated in a portrait of the human face (and it is destructive enough of truth there), should never be permitted to vitiate the value of an astronomical photograph. A defacing scratch, or a misleading defect, should be removed, but on no account should results be sought for that cannot be got by a skilful and straight development.

In conclusion, I wish to express my sincere obligations to Mr. G. W. Ritchey, of this Observatory, who has kindly and skilfully made for me nearly all of the lantern slides here presented.

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